In cooperation with the Bureau of Land Management

Erosion Resistance and Dust Emission on the Milford Flat Fire -- Can ESR Treatments Sometimes Worsen Wind Erosion?

Introduction

A major objective of post-fire Emergency Stabilization & Rehabilitation (ESR) treatments is to enhance erosion resistance and stabilize burned areas through the establishment of vegetation. Yet because mechanical treatments such as chaining and seeding with rangeland drills disturb soils for purposes of seed burial, ESR treatments also can have adverse impacts on soil stability. Treatment impacts on soil stability and erosion resistance generally are assumed to represent short-term trade-offs that are necessary for achieving long-term stabilization. Yet post-treatment monitoring efforts are rarely designed specifically to measure erosion resistance or soil movement, and there is no published research that examines treatment effectiveness in reducing rates of wind erosion and dust emission. To address this need for information, the U.S. Geological Survey (USGS) and the Bureau of Land Management (BLM) are collaborating on a project to monitor effects of ESR treatments on erosion resistance and dust emission in a portion of the Milford Flat Fire in west-central Utah. This project examines the effectiveness of ESR treatments in relation to treatment type, soil properties, and landscape setting.

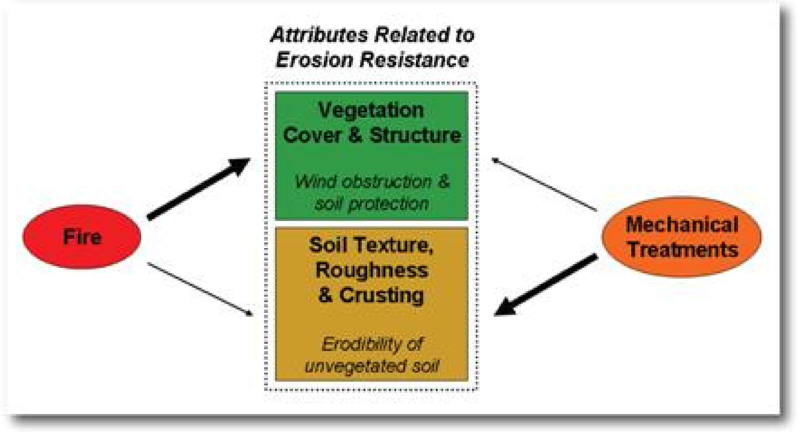

Figure 1. Conceptual diagram illustrating relative effects of fire and mechanical ESR treatments on attributes related to erosion resistance.

Study Area -- Milford Flat Fire

The Milford Flat Fire burned 147,000 ha (363,000 ac) in the eastern Great Basin in July 2007 and was the largest wildfire in Utah history. Within the fire perimeter, elevation ranges from 1390 to 2775 m and mean annual precipitation (MAP) ranges from 230 mm to 590 mm. Dust monitoring plots are located in the northwestern section of the burn where field observations and satellite imagery detected high levels of dust emissions during spring 2008 (Fig. 2). In this region of the burn, elevation is 1415-1500 m and MAP is 250-290 mm. Soils are derived from Pleistocene-aged lacustrine sediments and dune sands associated with Lake Bonneville, with silty clay loam (lacustrine sediments) and fine sandy (dune sands) surface textures. On fine-grained lacustrine sediments, unburned vegetation is dominated by shadscale (*Atriplex confertifolia*) and gray molly (*Bassia americana*) with well-developed biological crusts (Fig. 3a). Dune sands are dominated by four-wing saltbush (*Atriplex canescens*), Mormon tea (*Ephedra* sp.), and perennial grasses including Indian ricegrass (*Stipa hymenoides*), needle-and-thread (*S. comata*), and western wheatgrass (*Elymus smithii*).

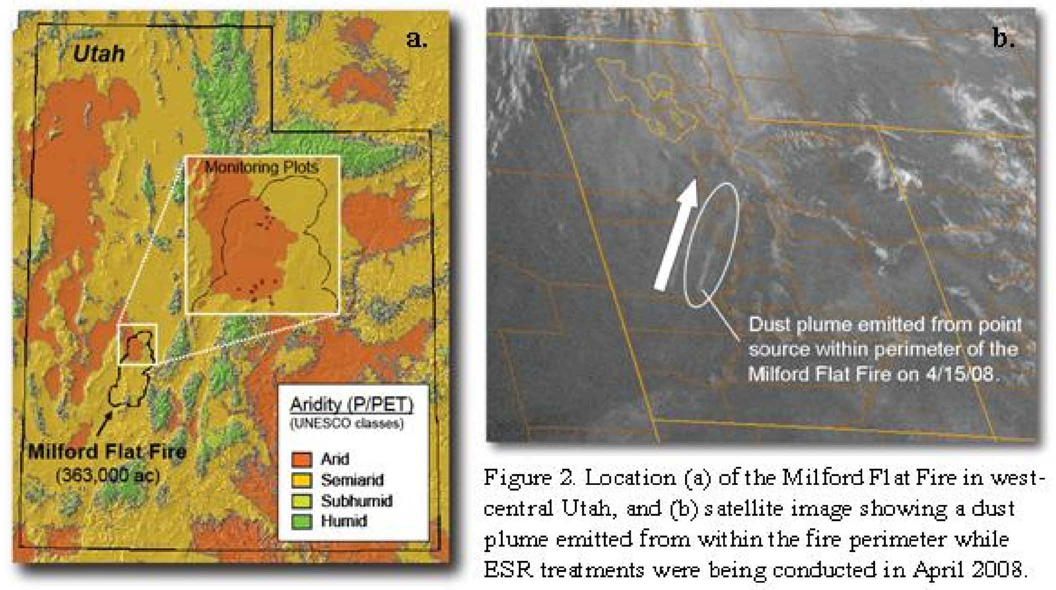

Figure 2. Location (a) of the Milford Flat Fire in west-central Utah, and (b) satellite image showing a dust plume emitted from within the fire perimeter while ESR treatments were being conducted in April 2008.

Study Design

Twenty-four monitoring plots were established in August 2008 to examine attributes of erosion resistance and seasonal patterns of dust emission in relation to three factors --

1. Substrate
   - Fine-grained lacustrine sediments
   - Dune sands
2. Burn status
   - Unburned
   - Burned
3. Type of ESR treatment
   - Untreated
   - Aerial seeding + Ely chain
   - Rangeland drill
   - Plateau herbicide + rangeland drill

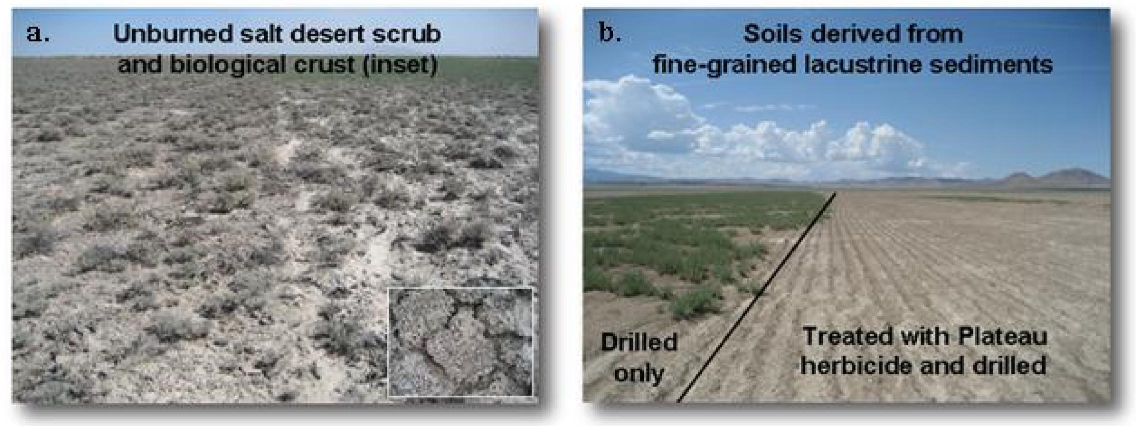

Figure 3. Unburned salt desert scrub (a) dominated by shadscale and biological soil crust on fine-grained lacustrine sediments, and (b) burned areas treated with a rangeland drill.

Field Methods

Soil and vegetation attributes related to erosion resistance are measured annually (Jul-Aug 2008-2010) using sampling techniques recommended for monitoring post-fire ESR treatments (Herrick et al. 2005, Wirth and Pyke 2006). Sampling occurs along three 50-m transects oriented as spokes radiating from the center of the plot. Attributes and sampling techniques include --

- Ground cover and foliar cover by species (line-point intercept technique),
- Gaps between plant canopies (line-intercept technique),
- Soil aggregate stability (field slake test), and
- Soil surface roughness (chain method; Saleh 1993).

Dust emissions are monitored with BSNE dust samplers mounted on a metal pole at the center of each plot at 15, 50, and 100 cm heights above the soil surface (Fig. 4; Fryrear 1986). Dust samples are collected three times per year (1 Jul, 1 Nov, and 1 Mar) to coincide with collection dates for other dust-monitoring efforts in the region.

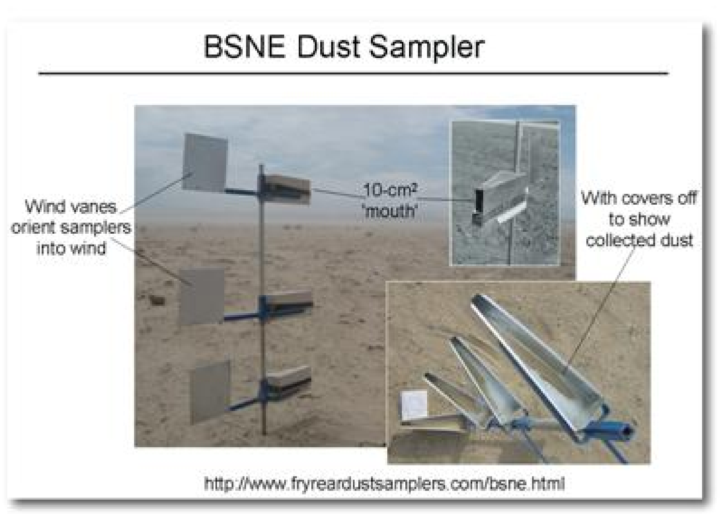

Figure 4. BSNE dust sampler used for monitoring dust emissions.

Results

Erosion Resistance

Data collected in August 2008 (one year post-fire) indicate that plots in treated areas were least resistant to wind erosion relative to plots in unburned areas and in burned areas that did not receive ESR treatments. Average bare ground was 46.4% in unburned plots, 68.7% in burned plots that were not treated, and 85.5% in burned plots that received ESR treatments (Fig. 5a). On fine-grained lacustrine sediments, burned plots receiving ESR treatments had soil aggregate stability values that were significantly lower than values in unburned plots and in burned plots that were not treated (Fig. 5b). Gaps between plant canopies also were largest in plots that received ESR treatments relative to unburned plots and burned plots that did not receive ESR treatments (Fig. 6).

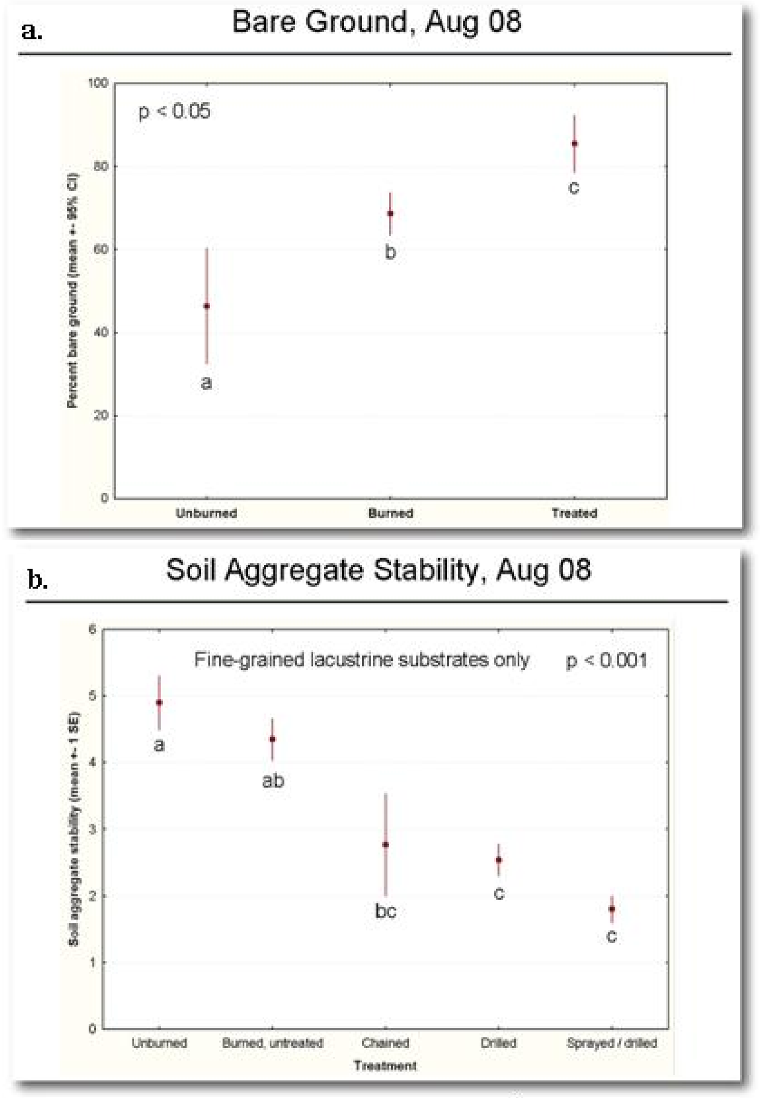

Figure 5. (a) Percent bare ground (means ± 95% CI) and (b) soil aggregate stability (means ± 1 SE) in August 2008 in unburned plots, burned / untreated plots, and plots receiving ESR treatments. Means annotated with the same letter are not significantly different.

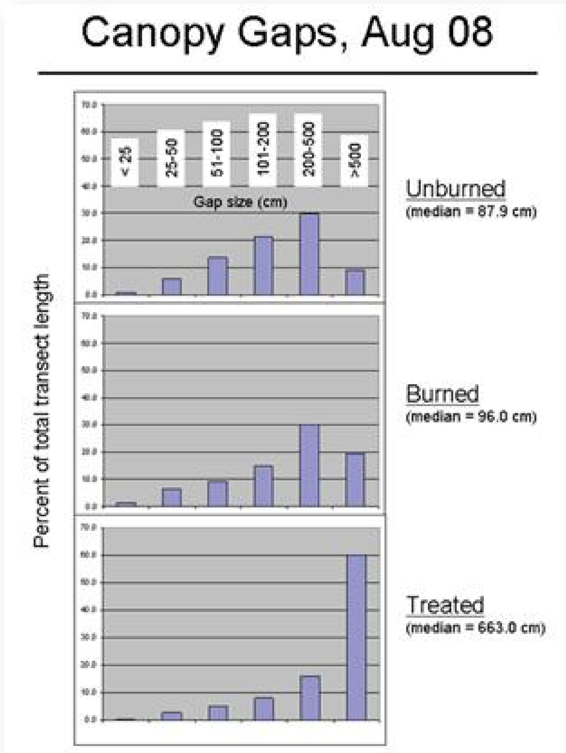

Figure 6. Percent of total transect length in size classes of canopy gaps in unburned plots, burned / untreated plots, and plots that received ESR treatments.

Figure 7. A canopy gap (from Herrick et al. 2005).

Horizontal Dust Flux

During the Aug-Oct 2008 period, rates of wind-driven soil movement (horizontal dust flux) at 15 cm above the soil surface varied over three orders of magnitude and were greatest in plots that received ESR treatments, were in exposed landscape settings, and had soils that were highly susceptible to wind erosion (silty clay loam lake sediments with a veneer of fine sand). Fluxes were 6.2 - 93.5 g m^{-2} day^{-1} in unburned plots, 8.3 - 579.1 g m^{-2} day^{-1} in burned/untreated plots, and 17.6 - 19,800.4 g m^{-2} day^{-1} in burned plots that received ESR treatments (Fig. 8). Maximum dust fluxes in plots that received ESR treatments were 2.0 - 5.8 times greater than maximum fluxes (approx. 3,400 g m^{-2} day^{-1}) documented during nine years of monitoring at low-elevation sites on the Colorado Plateau (Belnap et al., submitted).

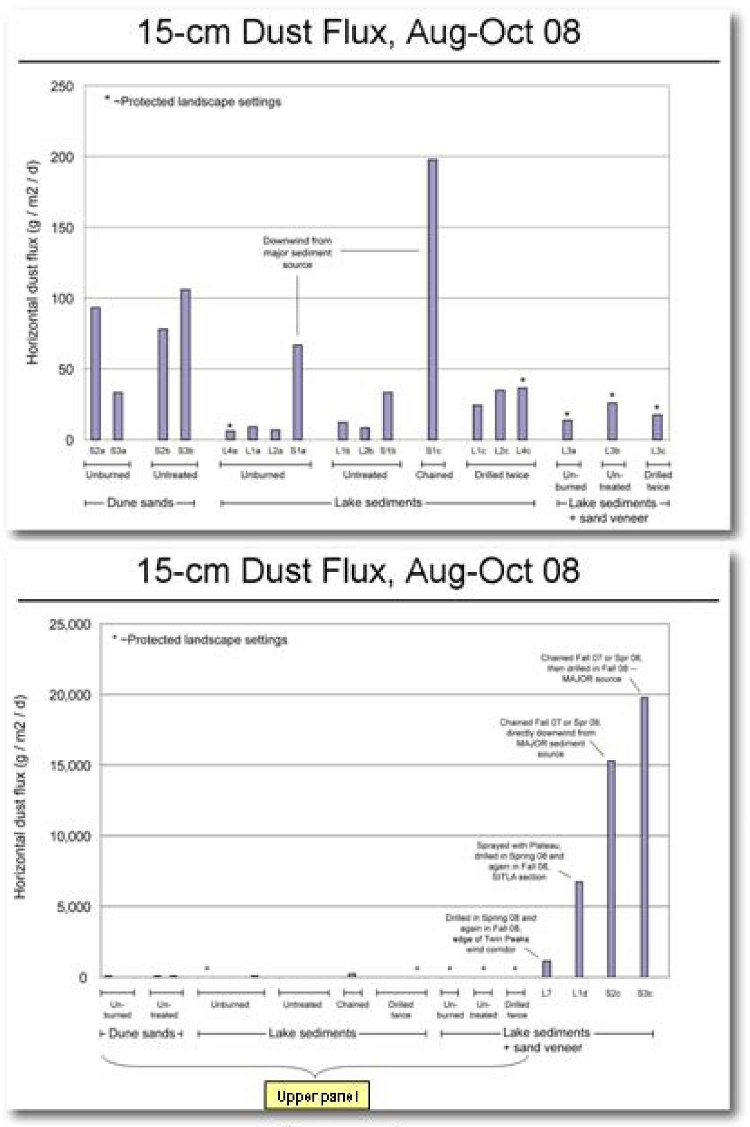

Figure 8. Horizontal dust fluxes at 15 cm during the period Aug-Oct 2008 in relation to landscape setting (protected or exposed), substrate, and treatment type (unburned; burned but untreated; and chained, drilled, or sprayed and drilled). (Data from upper panel are included in lower panel -- note difference in scaling of y-axes.)

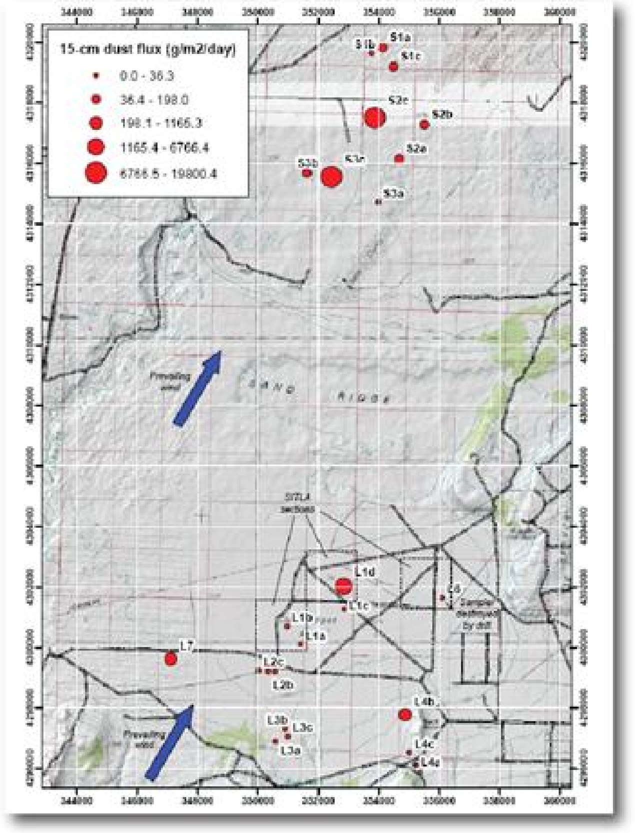

Figure 9. Map of plot locations in study area at northern end of the Milford Flat Fire, with plot symbols (red points) scaled by Aug-Oct 08 dust fluxes at 15 cm. Note that symbols are *graduated*, not *proportional*. See Fig. 8 for actual flux values.

Discussion

Wind Erosion -- Controlling Factors Beyond Management Control

Several factors beyond management control contribute to the high potential for wind erosion in the study area.

• **Highly Susceptible Soils**: Dune sands provide an abundant source of *saltating soil particles* that *sand-blast fine-grained lake sediments*, causing them to become suspended and transported far downwind (Okin et al. 2006).

• **Arid Climate**: The study area is *arid* (Fig. 2a), thus resulting in a low probability of plant establishment in response to ESR treatments.

• **Highly Exposed Landscape Setting**: The area is situated on a basin floor with a *very high degree of wind exposure* and wind corridors created by topographic features. (Aerial photographs illustrate the dominance of eolian landforms, and a wind farm is under construction south of the study area.)

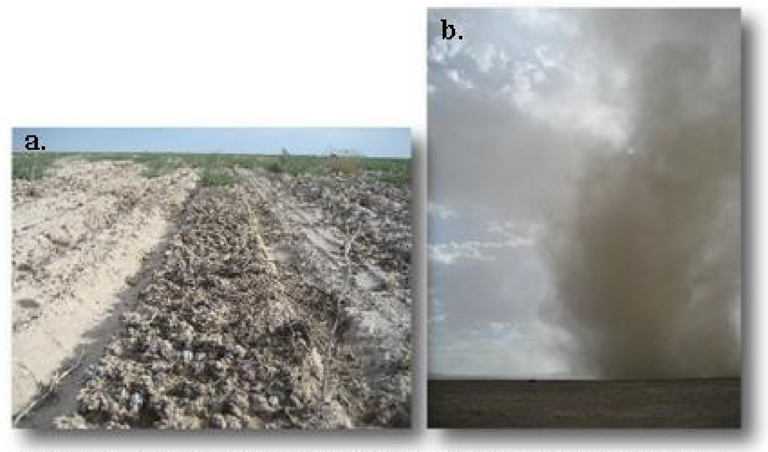

Figure 10. (a) Swath of well-developed biological soil crust between furrows created by a rangeland drill, and (b) a dust plume arising from a burned area treated with herbicide and a rangeland drill.

Effects of Fire and ESR Treatments on Erosion Resistance and Dust Emission

In settings such as the study area where there is a naturally high potential for wind erosion, it is especially important for decision makers to critically evaluate relative impacts of fire and ESR treatments on erosion resistance. *Data collected one year post-fire strongly suggest that ESR treatments thus far have had greater adverse impacts on erosion resistance than the fire itself.* This is primarily due to treatment impacts on soil erodibility (destabilization of soils through disturbance of intact biological crusts, and alignment of drill furrows with prevailing winds), and secondarily due to treatment impacts on vegetation structure (suppression of annual plants). Where such impacts of ESR treatments coincided with highly exposed landscape settings and highly susceptible soils (fine-grained lacustrine sediments with a veneer of fine sand), it is probable that treatments themselves greatly contributed to the high dust emissions detected by satellite imagery (Fig. 2b) and documented during the first period of dust sampling (Fig. 8). These dust emissions have the potential to impact air quality, the duration of mountain snowcover (Painter et al. 2007), and alpine ecosystems (Neff et al. 2008) far downwind of the study area.

How do we Assess Risks of Post-Fire Treatment Strategies?

Recent advances in erosion modeling have the potential to improve managers' ability to evaluate the relative importance of vegetation structure and soil-surface properties as dynamic controls of wind erosion in different landscape settings (Okin et al. 2006, Okin 2008). Such information can be used to enhance decision makers' ability to assess relative risks of different management strategies, whether in relation to fire or other issues.

Motivated in part by this research, Figure 11 presents a conceptual model illustrating the interactive effects of vegetation structure (scaled canopy gaps) and soil erodibility on wind erosion. Curves illustrate the sensitivity of wind erosion to changes in soil erodibility for a fixed configuration of vegetation structure (e.g., x_1 in Fig. 11a). Notably, the model suggests that as gap sizes increase (i.e., as plants become smaller and spaced farther apart), there is a level (x_2) beyond which wind erosion becomes relatively insensitive to vegetation structure and is almost entirely controlled by soil-surface properties that determine erodibility. This has tremendous implications for management of arid landscapes with naturally low amounts of vegetative cover (e.g., Fig. 3a).

These concepts can be applied to illustrate relative effects of fire and ESR treatments on wind erosion in the study area (Fig. 11b). Wildfire reduced vegetation structure but had lesser direct impact on soil erodibility (e.g., Fig. 5b), resulting in a slight increase in wind erosion (shift from 1 to 2 in the diagram). ESR treatments further reduced vegetation structure (in short term), but had relatively large impacts on soil erodibility -- resulting in a large increase in wind erosion (shift from 2 to 3 in the diagram).

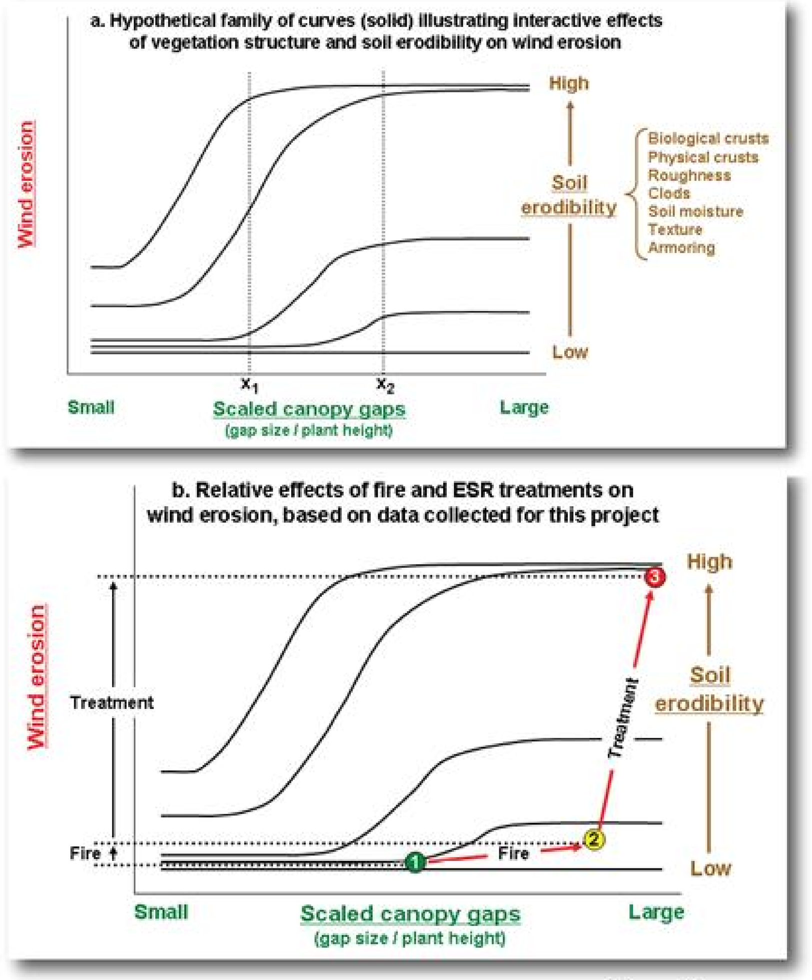

Figure 11. (a) Conceptual model illustrating interactive effects of vegetation structure and soil erodibility on wind erosion, and (b) application of the model to illustrate relative effects of fire and ESR treatments on wind erosion in the study area (motivated by Okin 2008 and Okin et al. 2006). See text for explanation.

Take-Home Points

- Monitoring is rarely conducted to evaluate effects of post-fire ESR treatments on erosion resistance and dust emission.
- Data collected thus far suggest that ESR treatments in the study area had greater adverse impacts on erosion resistance and dust emission than the fire itself.
- Managers need better tools for assessing relative risks of different post-fire management strategies, particularly in arid landscapes where climatic conditions greatly limit plant establishment and the effectiveness of post-fire ESR treatments.

Acknowledgements

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